KITAMI Institute of Technology
Transportation Engineering Lab.

PDRG Meeting JRPUG2022

Human-centered Evaluation of Localized Surface Roughness in Terms of Biosignals

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Introduction

1). Kawamura, K., and Kamiya, K., 2007. Current status and issues of pavement rehabilitation in NEXCO. Asphalt, Vol.50, No.222.
2). Kamiya, K., 2021. Life Cycle Analysis of Road Pavement utilizing NEXCO-PMS. PDRG Meeting JRPUG2021.

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Specific criteria

- $IRI_{Fix}(200) \leqq 3.5$ mm/m
- $IRI_{Fix}(10) \leqq 8.0$ mm/m

➢ The IRI assumes an average evaluation

- underestimates road surface conditions including localized deformations

Porous asphalt pavements

- with polymer-modified asphalt as the surface layer

- Localized deformation[1)]
- Damage deepens over time[2)]

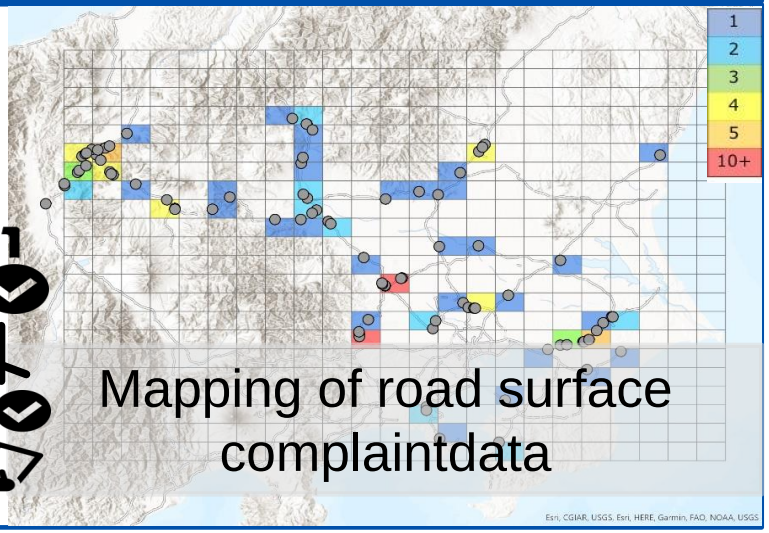
Complaints regarding ride quality

Period covered: FY2020 (April 2020 - March 2021)

- Over 100 of complaints +66.2% (YoY)

Problem to be solved

A gap between the road surface rating based on the specific criteria and the expectation of road users for the ride quality



Mapping of road surface complaintdata

Research Flow and Purpose

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Step 1

method: Field survey on expressway (where users often inquire about road surface damage)

purpose: Get data: road surface profile + vehicle vibration + physiological information + driving video

Step 2

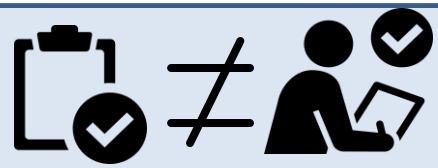
method: Driving simulator experiment

purpose: Identification of road surface roughness as stressors

Step 3

method: Evaluate road surfaces with a focus on biosignals

purpose: Elucidating the Gap



Research Flow and Purpose

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Step 1

Field survey on expressway
(where users often inquire about road surface damage)

Get data:

The final objective of this research is to identify unique road surface roughness that cannot be evaluated by current management standards, which is necessary to establish human-centered management standards through the above three steps

Step 3

method: Evaluate road surfaces with a focus on biosignals

purpose: Elucidating the Gap

Field survey

Step 1 | Step 2 | Step 3

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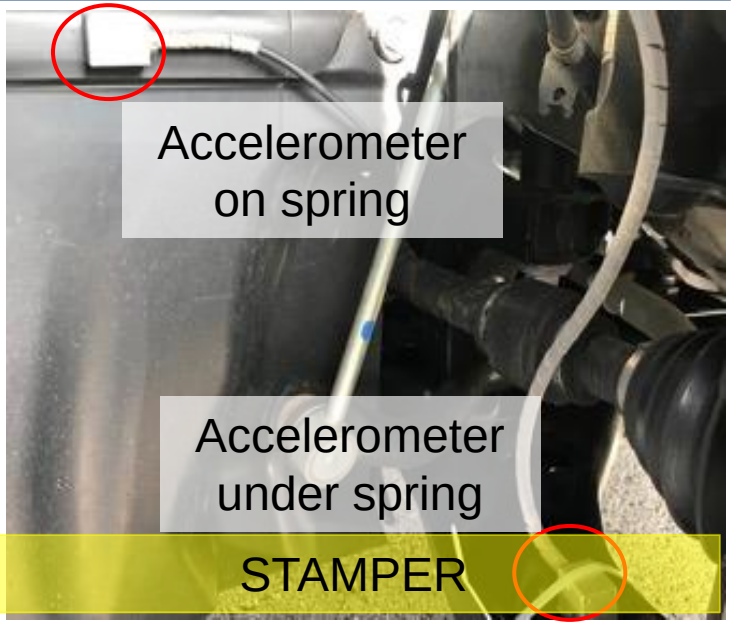
Mobile profilometer (MPM)	Video footage	Biosignals	Diagnosis by sight and feel
•Road surface profile •IRI •Location information	•Check road surface conditions	•Check stress	•Check the extent of damage



class	Type※
1 1.5	Ⅰ
2 2.5	Ⅱ
3	Ⅲ

※Evaluation of Soundness, Pavement Inspection Procedure

✓Selection of the section to be used for the DS experiment was made.

DS Experiment

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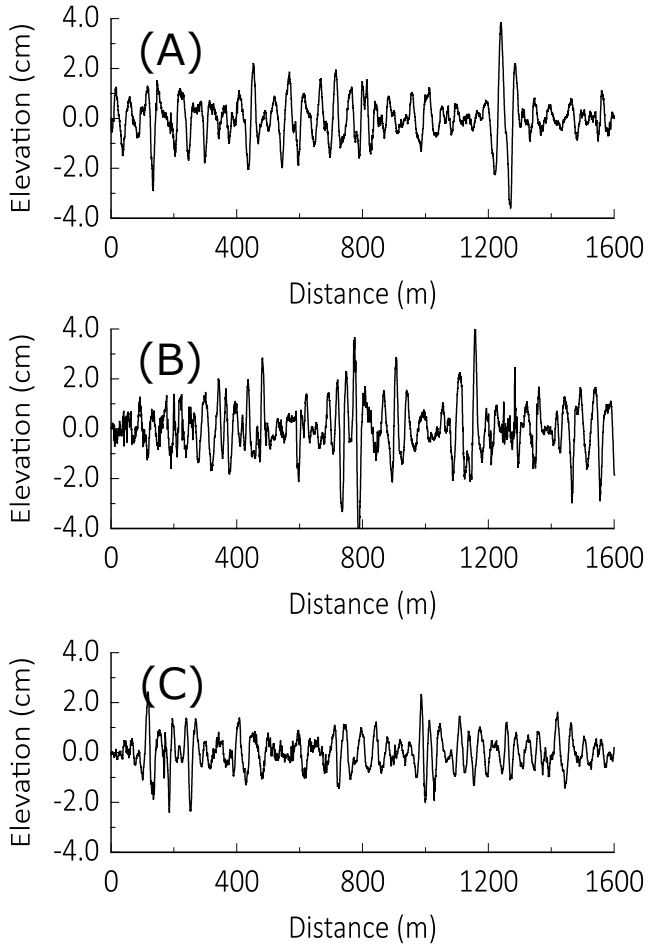
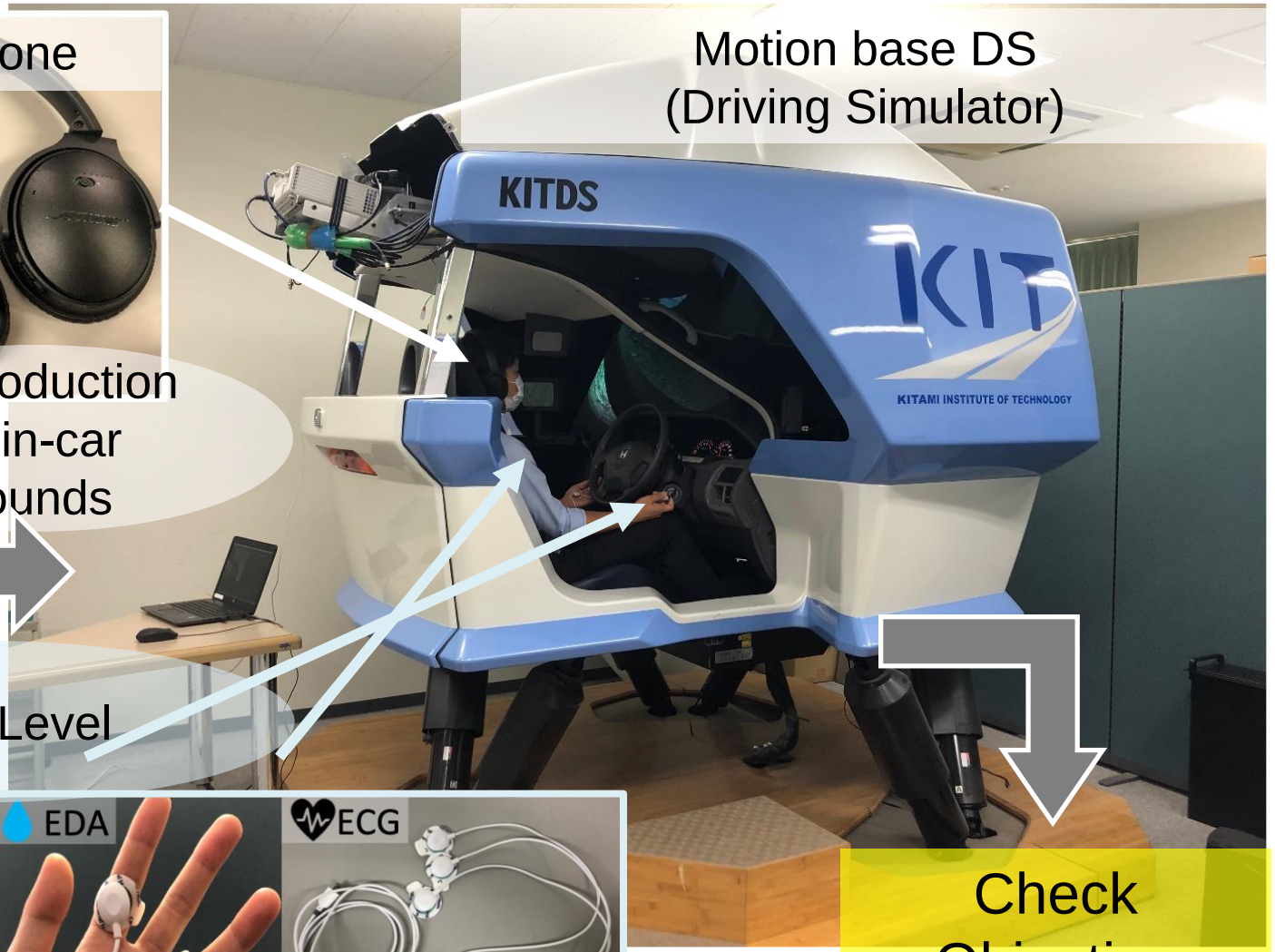
Road surface profiles obtained from actual road survey



Headphone

Reproduction of in-car sounds

Motion base DS (Driving Simulator)



Stress Level

Check Objective User Evaluation

DS Experiment

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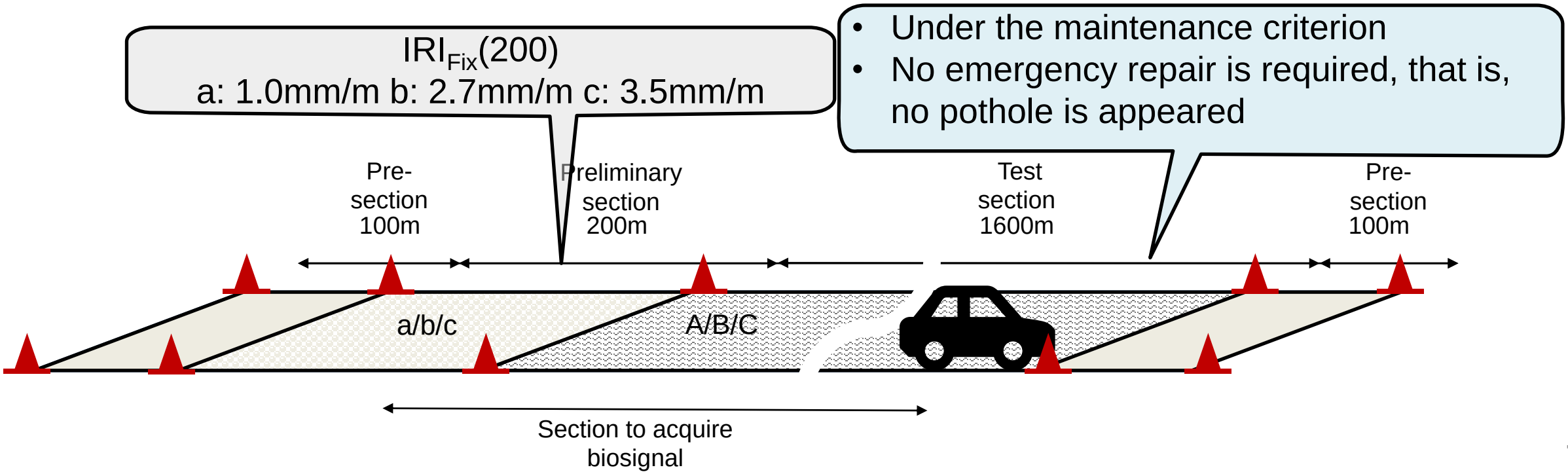
Test Scenario

(1). Speed: 80km/h (constant)

(2). Road surface condition
- Preliminary section(A/B/C)
- Preliminary section(a/b/c)
- Reference section(IRI_{Fix}(200) = 1.7mm/m)

(3). Trial time: about 2 min
Total time: about 22 min

(4). Participants: 17 (M, 20s to 50s,Ave:30.8)



Biosignals interpretation

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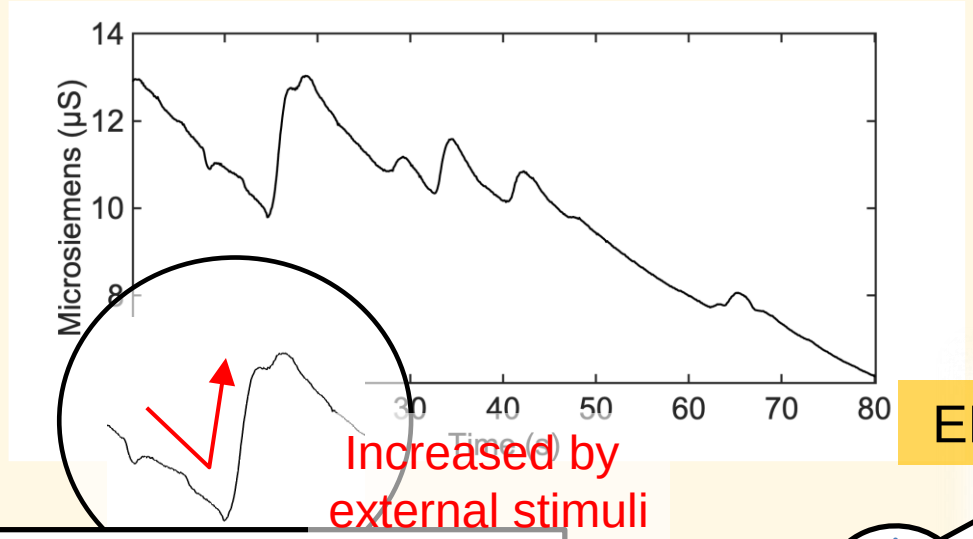
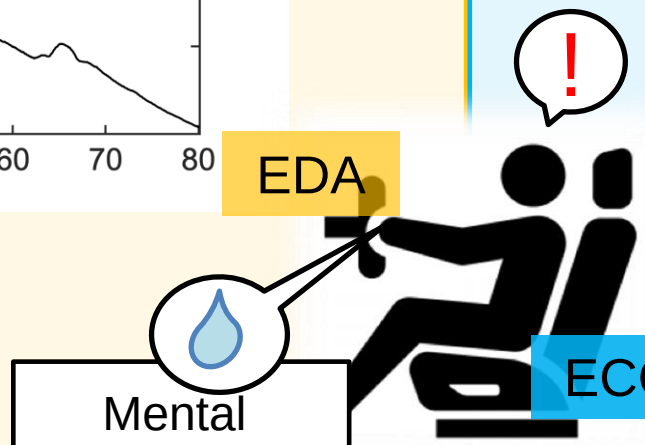
Electrodermal activity (EDA)



Increased by external stimuli

Skin Conductance Response (SCR)

EDA

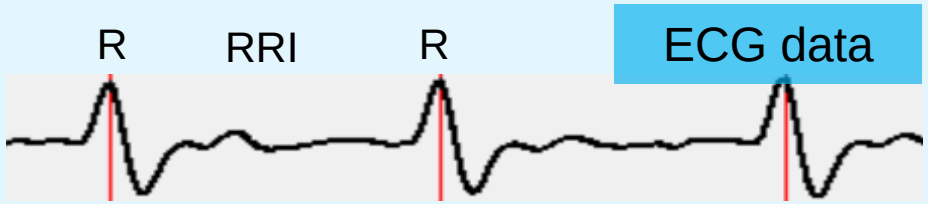


ECG

Mental sweating

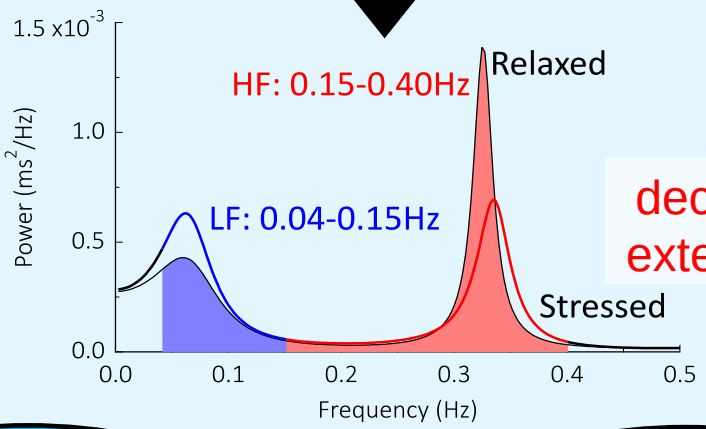
SCR Occur ▶ Mental stress

Heart Rate Variability (ECG)



RRI(R-R Interval)

Frequency analysis of RRI



decreased by external stimuli

HF Decrease ▶ Mental stress

Road surface evaluation Method

Step 1 | Step 2 | Step 3

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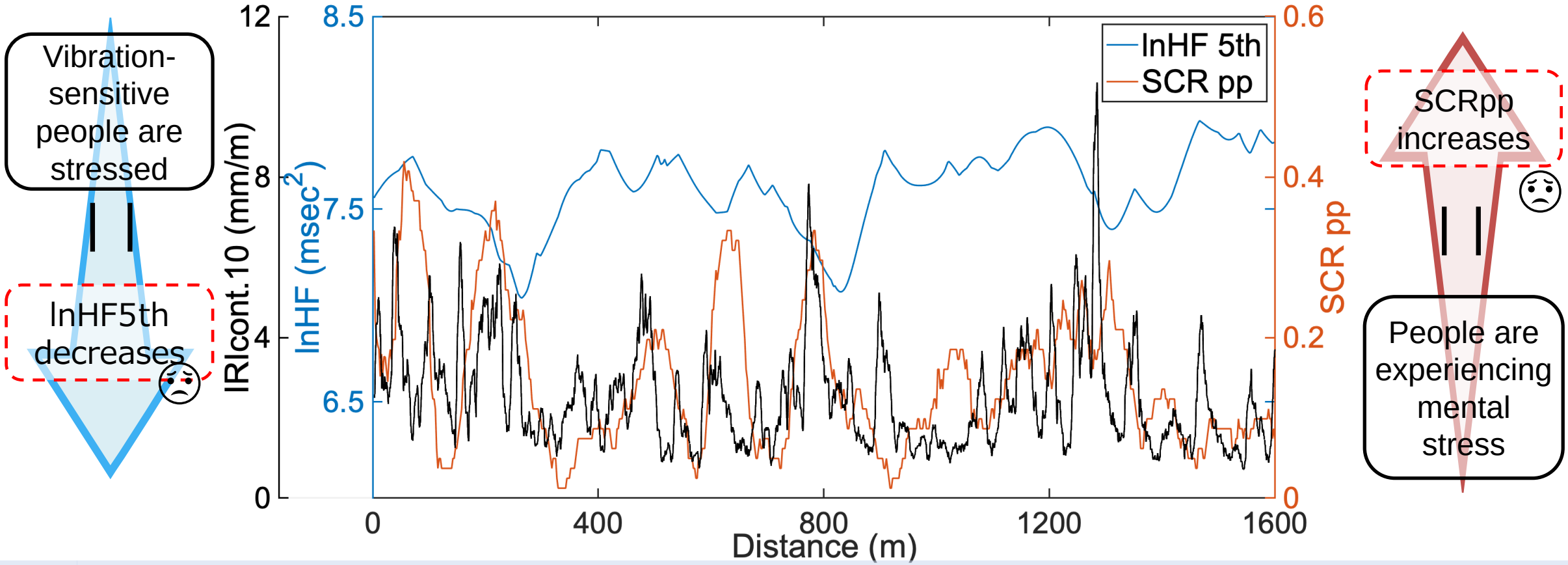
Changes in Mental Stress against IRI



- At a distance of about 200 m, the mental stress is detected even though the IRI below the current maintenance criteria
- At a distance of about 500 m, no mental stress was observed

Results and Discussion

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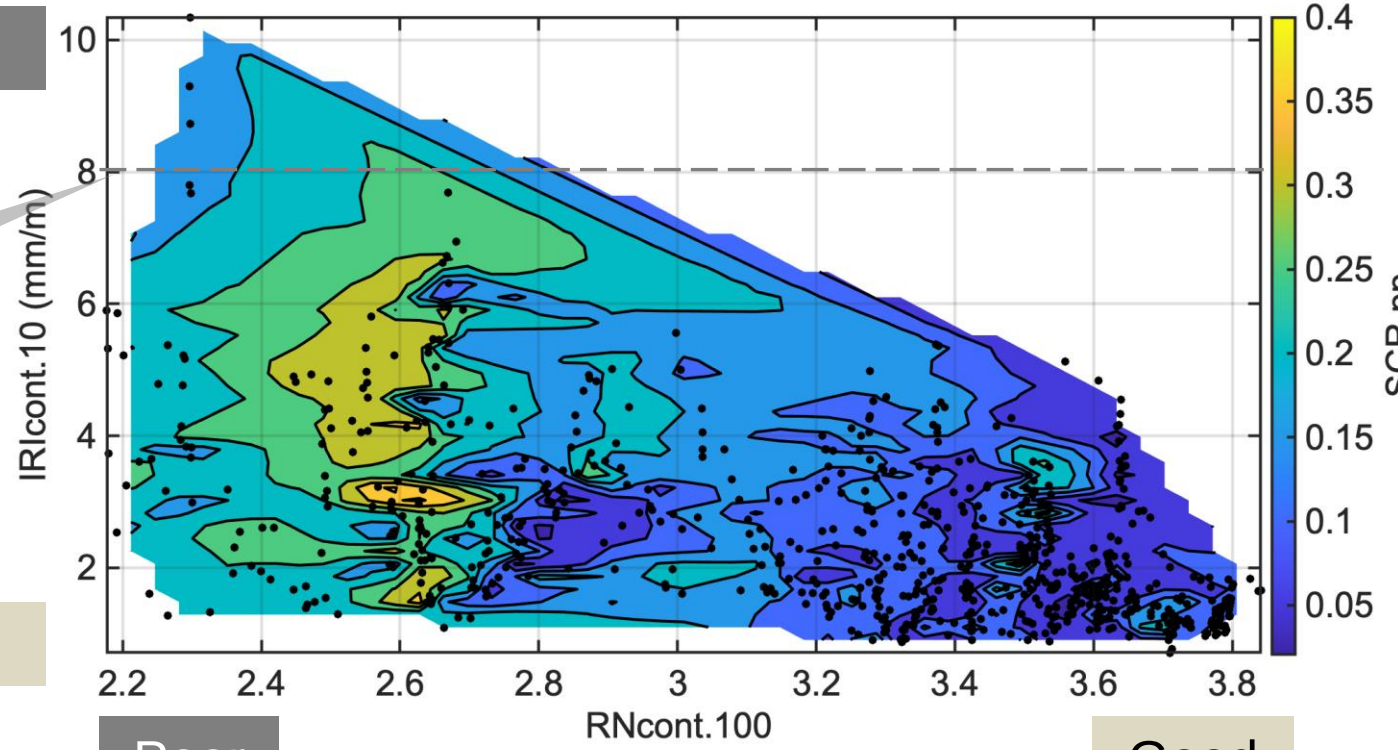
Relationship of SCRpp with IRI and RN

Poor

The criteria

Good



High Stress

Low Stress

Poor

Good

IRI: 4~6 mm/m
RN: 2.4~2.6
SCRpp increases

IRI underestimates the surfaces that people find stressfull

Results and Discussion

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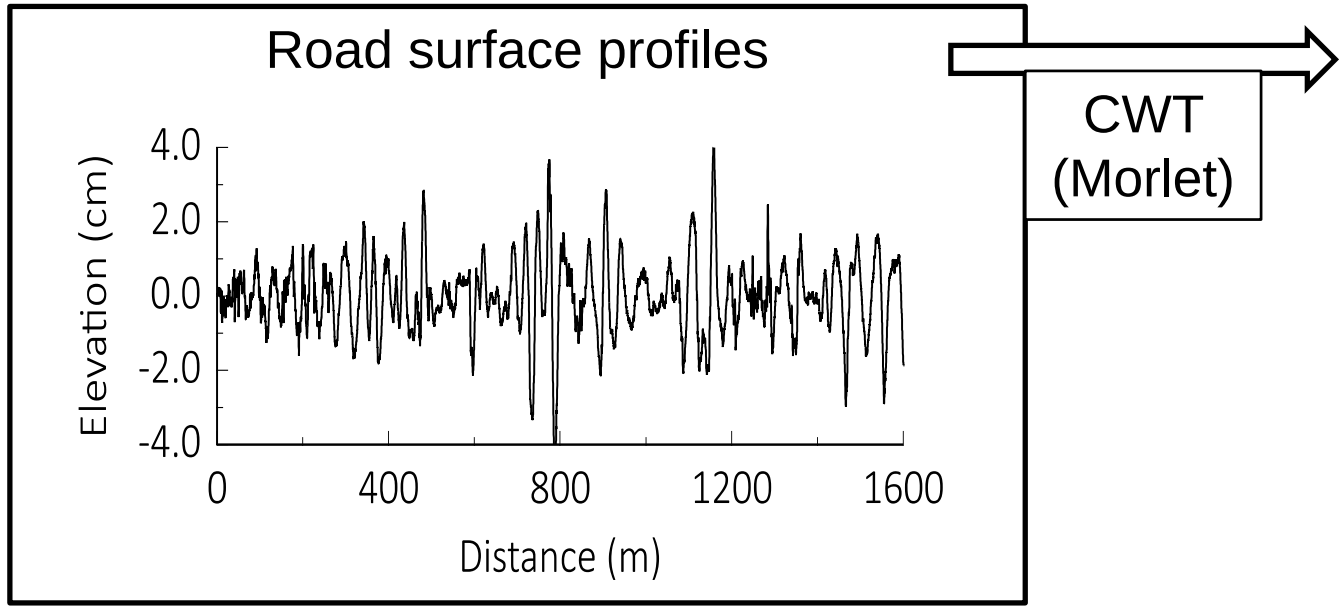
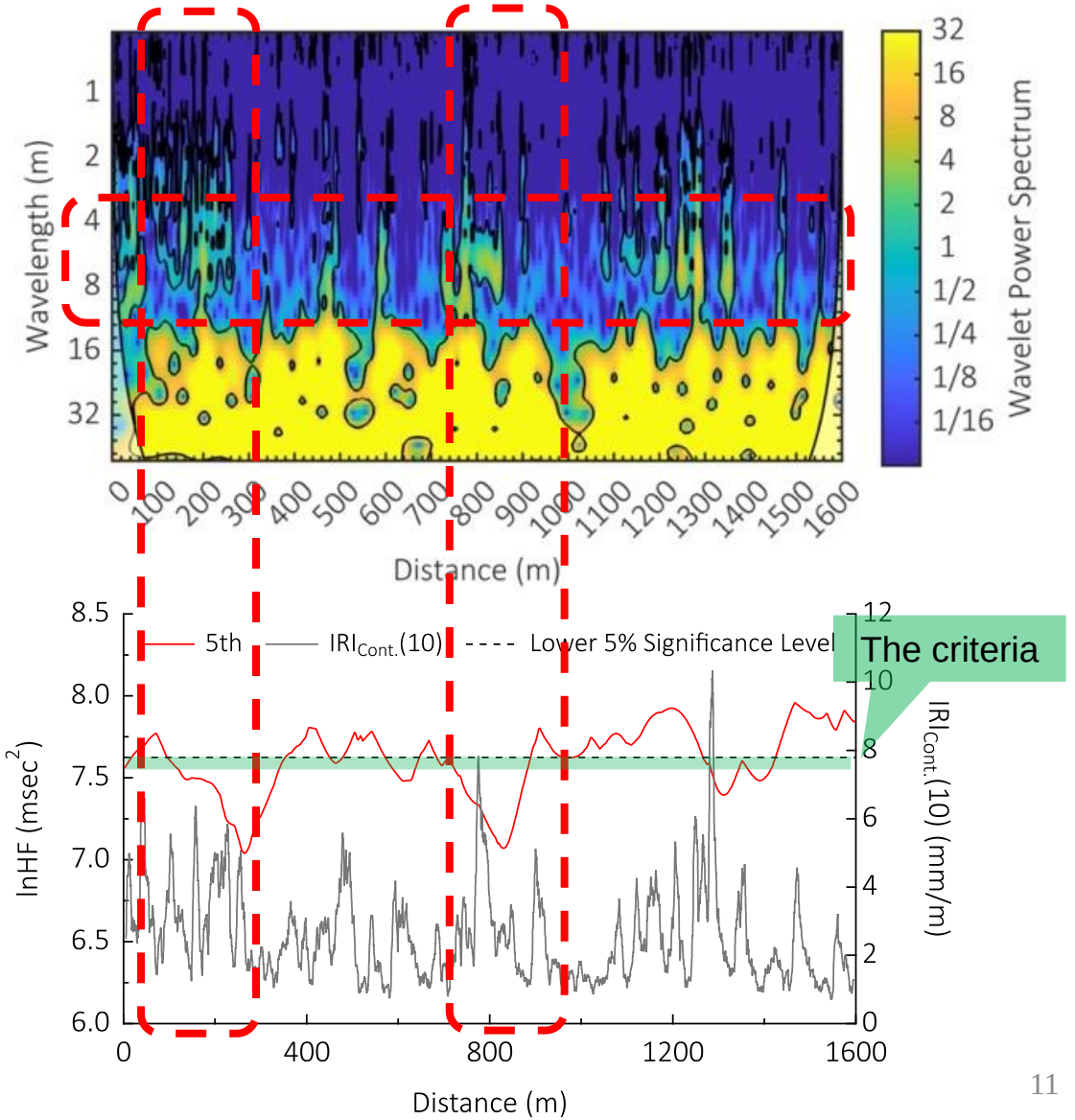
Relationship between the Road Surface Characteristics and Mental Stress



CWT (Morlet)



The mental stress responds to the wavelength ranging from 4 to 8 m even if the IRI reveals an acceptable level

Results and Discussion

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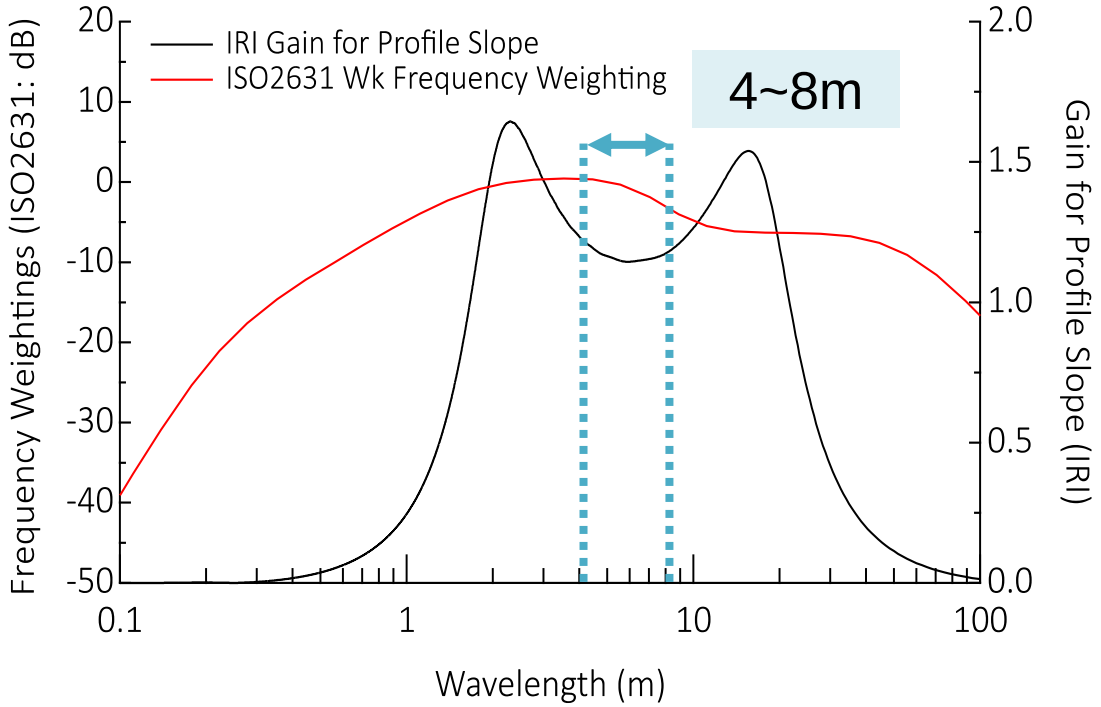
About Wavelength 4-8m

- The IRI is less sensitive to the wavelength ranging from 4 to 8 m.
- The sensitivity range of the human body for vertical vibrations is 4~8 Hz (ISO,1997) corresponding to the wavelength ranging from 2.8 to 5.6 m (speed: 80km/h)



QC model response and human vertical vibration sensitivity at a speed of 80 km/h

The maintenance criteria with IRI are inconsistent with the mental stress corresponding to complaints of road users

Conclusion

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- The relationship between biosignal and road surface wavelength
  - ✓ Surface roughness inducing mental stress is potentially underestimated by the IRI.
- Relationship between the Road Surface Characteristics and Mental Stress
  - ✓ The mental stress increases with increasing amplitudes of wavelength ranging from 4 to 8 m of a profile even if the IRI reveals an acceptable level.
- Wavelength response sensitivity
  - ✓ The insensitivity of IRI to wavelengths between 4 and 8 m generates the gaps between the maintenance criteria in terms of the IRI and the road user rating.